Laboratory-and field-based assessment of maximal aerobic power of elite stand-up paddle-board athletes

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Laboratory and field based assessment of maximal aerobic power of elite SUP athletes

Original Investigation

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ABSTRACT

Purpose: Stand up paddle boarding (SUP) is a rapidly growing sport and recreational activity where only anecdotal evidence exists for its proposed health, fitness and injury rehabilitation benefits.

Methods: A total of 10 internationally and nationally ranked elite SUP athletes volunteered to participate in this study. Elite SUP athletes were assessed for their maximal aerobic power on an ergometer in a laboratory and compared to other water based athletes. Field based assessments were subsequently performed utilising a portable gas analysis system and a correlation between the two measures was performed.

Results: The mean VO_2max (relative) was significantly higher (P =0.037) when measured in the field with a portable gas analysis system (45.48±6.96ml/kg/min) when compared to laboratory based metabolic cart measurements (43.20±6.67ml/kg/min). There was a strong, positive correlation (r=0.907) between laboratory and field maximal aerobic power results. Significantly higher (P=0.000) measures of SUP paddling speed (m/s) were found in the field when compared to the laboratory ergometer (+42.39%). There were no significant differences in maximal heart rate between the laboratory and field settings (P=0.576).

Conclusion: The results demonstrates the maximal aerobic power representative of internationally and nationally ranked SUP athletes and shows that SUP athletes can be assessed for maximal aerobic power in the laboratory with high correlation to field based measures. The field based portable gas analysis unit has a tendency to consistently measure higher oxygen consumption. Elite SUP athletes display aerobic power outputs similar to other upper limb dominant elite water based athletes (surfing, dragon boat racing and canoeing).

Key words: profiling, water, sports, aquatic, paddle boarding, SUP

INTRODUCTION

Stand up paddle boarding (SUP) is a new sport and recreational activity, which is increasing in popularity around the world due to its proposed health and fitness benefits and enjoyment [1]. Stand up paddle boarding is a hybrid of surfing and paddling in which participants can either distance paddle and/or surf waves [2]. Many websites anecdotally advocate the use of SUP to increase strength, fitness, core stability, balance and decrease back pain. However, our recent review of the literature utilising the search terms “SUP”, “Stand Up Paddle Boarding” and “Stand Up Paddle” of CINAHL, SPORTDiscus, EMBASE & Medline found no scientific evidence to substantiate these proposed benefits.

An ideal physiological test is one which accurately and reliably assesses the specific energy systems of the musculature involved in that particular sport [3]. To adhere to the principle of specificity, in addition to laboratory testing, field testing for aerobic power on a stand up paddle board is highly desirable. This allows comparison between testing in a laboratory under tightly controlled conditions and actual SUP performance on water.

Recent advances in technology have allowed for more compact, light-weight and ambulatory pulmonary gas analysis system (Cosmed K4b2, Rome, Italy). The development of such systems has allowed field testing to gain a greater understanding of the metabolic demands during various modes and intensities of exercise in the environment in which they are normally performed [4].

An indication of the aerobic capacity of elite SUP athletes provides a guideline for an individual wanting to succeed in competitive SUP. The measurement of aerobic fitness of internationally

and nationally ranked SUP athletes has yet to be quantified, leaving a gap in the scientific literature. Therefore, the purpose of this study was to assess internationally and nationally ranked SUP athletes in the laboratory under tightly controlled conditions, then compare the result to a field based assessment with a portable gas analysis system.

METHODS

SUBJECTS

A total of 10 elite competitive (6 males & 4 females) SUP athletes were recruited from the Stand Up Paddle Surfers Association (Gold Coast, QLD, Australia). Of the elite competitors, six were rated amongst the top ten in the world and the remaining athletes were currently competing in the national competition of SUP in Australia. For inclusion, athletes were without a history of back pain and were free from any physical and psychological impairment. The study was approved by the University Human Research Ethics Committee (RO-1550) and each participant formally consented to taking part in the study.

DESIGN

This was a comparative study in which athletes were tested for maximal aerobic power in the field with a portable gas analysis system and subsequently in the laboratory under tightly controlled conditions. The primary aims of this study were to assess elite SUP athletes for their maximal aerobic power on an ergometer in a laboratory and compare the results to other water based athletes. The secondary aim was to compare the laboratory result to a field based measurement utilising a portable gas analysis system.

METHODOLOGY

Athletes attended the laboratory where a continuous graded exercise test on a specialised SUP ergometer (KayakPro SUPErgo, Miami, FL, USA) was used to determine maximal aerobic power (relative and absolute). Maximal aerobic power (VO_{2max}) was determined using an automated expired gas analysis system (Parvomedics TrueOne 2400 metabolic system, East Sandy, Utah, USA) which was calibrated (gas analyzers and ventilation) prior to each test. The expired gas analysis system meets Australian Institute of Sport accreditation standards for precision and accuracy. The gas analysis software was configured to breath-by-breath for collection however VO_2 max was determined from the average of 30 seconds of max data collected.

The SUP ergometer VO_2max protocol involved the athletes starting at an initial power output of 5W with a 5W increase each minute until volitional exhaustion. The athletes were instructed to paddle as per normal, free to alternate paddling on each side ad libitum. Heart rates were monitored throughout the test with a 12 lead ECG via telemetry (figure 1).

A portable gas analysis system (Cosmed K4b2, Rome Italy) previously validated for field assessment of VO_{2max} in a number of outside activities [4], was utilized to assess expired concentrations of oxygen and ventilation (figure 1). For comparison to laboratory findings, the athletes then completed a VO_{2max} test whilst on flat water in a creek (tide neutral).

The protocol for the field based assessment of maximal aerobic power involved starting at 30 strokes per minute keeping cadence with a metronome played to the athletes through headphones attached to a portable media player (iPod). The metronome increased cadence by 5 strokes per minute every minute which the participant was to maintain until volitional fatigue. All water

based VO_{2max} tests were conducted within five days of the laboratory tests to ensure minimal physiological change to maximal aerobic fitness.

STATISTICAL ANALYSIS

All statistical analyses were performed using SPSS (Version 20) including mean and standard deviation calculations, while paired *t* tests were used to determine any significant differences between the two groups. Alpha was set at 0.05 *a priori.* A Pearson correlation analysis was performed to compare laboratory results to field results. A Bland Altman plot [5] was utilised to provide a graphical representation of the two different measurement techniques, with limits of agreement set at 95%.

RESULTS

Table 1 displays that males were younger (-9.42%) but not significantly (*P*=0.627), significantly taller (+8.82%, *P*=0.006) and significantly heavier (+21.37%, *P*=0.044) than the female athletes. The overall group, and female Body Mass Index (BMI) was within the healthy weight category with the males being classified as overweight despite being only slightly more than the females (+2.78%).

<Table 1 here>

Field based results of aerobic power for the group, were significantly higher (+5.28%, *P*=0.037) as compared to laboratory based results (Table 2). A significant (*P*=0.000) difference was found in peak speed measured in the field (+42.39%) compared to in the laboratory. There were no significant differences in heart rate measured between the field and laboratory (*P*=0.576). Males had a significantly greater maximal aerobic power as compared to females in both the laboratory

(47.59±3.37 vs 36.61±4.24ml/kg/min, *P*=0.002) and in the field (49.68±4.41 vs 39.18±4.96 ml/kg/min, *P*=0.008). There were no significant differences between genders with regard to ventilation (VE), Respiratory Exchange Ratio (RER), or heart rate in the laboratory when compared to the field.

<Table 2 here>

A high, positive correlation (r=0.907) was found between the absolute VO_{2max} recorded in the laboratory and in the field with the portable gas analysis unit (Figure 1). The field measurement was higher in 80% of the subjects tested with only 2 subjects demonstrating higher VO_{2max} values in the laboratory. The mean difference between the two samples was only -2.28 ±2.95 ml/kg/min. A linear regression of the differences of the mean demonstrated that there was no proportional bias between the two measures (*P*=0.785). There was however, fixed bias (*P*=0.037) as the measurements in the field were consistently higher than the laboratory based measurement.

<Figure 1 here>

<Figure 2 here>

DISCUSSION

The primary aim of this study was to measure the maximal aerobic power of elite SUP athleteswith a traditional laboratory based method utilising a metabolic cart and compare the results to other water based athletes. The secondary aim of this study was to compare the

laboratory based result to a field based result utilising a portable gas analysis unit. The aerobic power of elite SUP athletes has not previously been reported in the literature and the findings from this study provide some insight into the maximal aerobic fitness levels of elite SUP athletes.

The elite male athletes profiled in this study displayed high levels of maximal aerobic power as reported in other water sports which are upper limb dominant. For example, previous investigators have reported male surfer's maximal aerobic fitness ranging from 37.8ml/kg/min to 54.2ml/kg/min [6,7], canoeists from 44.2ml/kg/min to 51.9ml/kg/min [8,9] and dragon boat racers from 42.3ml/kg/min to 50.2ml/kg/min. Although female surfers have been tested for maximal aerobic fitness whilst running on a treadmill [10] and cycling [11] there is currently a minimal amount of normative data for upper limb specific VO_2 max testing for female water based athletes. The maximal aerobic fitness of these female SUP athletes (36.61 ± 4.24ml/kg/min) is similar to as yet unpublished data for elite female surfers we have tested on a swim bench ergometer of 34.30 ± 2.71 ml/kg/min [12].

The pooled data of both male and female values from the field based test demonstrated a high level of correlation between those results obtained from controlled laboratory based test. Given our results, it would appear that laboratory assessment of maximal aerobic power in elite SUP athletes is a valid alternative to field based testing. The tendency of the K4b2 portable unit to record consistently higher oxygen consumption than laboratory based metabolic carts has been found in other research [4]. The differences in the two environments as evident by the fixed bias error may be attributed to athlete comfort and familiarisation when in their natural SUP environment on water. The athletes reported they felt more comfortable completing the maximal

aerobic power test whilst on the water, despite wearing the portable gas analysis device which weighed 800 grams and required a utilization of a facemask to collect expired gasses for the duration of the test.

The differences in speed measures between the two environments are most likely attributed to the different methods for quantification of speed. The laboratory based speed measure is based upon measurement of the moment of inertia of the flywheel on the ergometer whereas the field based measurement was from the K4b2's integrated global positioning system (GPS). The GPS component of the K4b2 was only a 1Hz unit, which is a significantly lower frequency than the more modern, updated 15Hz units which are currently available. Previous research had reported quantification of speed via GPS is associated with measurement errors when sampling rates are low [13]. Field based measurement of speed with lower GPS sampling rates should therefore be interpreted with caution amongst this population. Our current research on field based assessment of speed in SUP utilized 15Hz GPS units, which identified an average speed of 2.72±0.2m/s during a marathon SUP event (~20km). Further research is therefore required to determine speed measurements across the water whilst SUP.

A limitation of this study is that two different protocols were used. Unfortunately, we were unable to instrument the SUP paddle to ascertain power outputs for the field assessment therefore a protocol was devised where an incremental increase in stroke rate was used. This was not feasible to replicate in the laboratory as once the subjects stroke rate reached 55 strokes per minute (and higher) athletes were unable to maintain normal strokes and consequently shortened their stroke rate in an attempt to maintain the designated cadence. For example, the average

stroke lengths found in this study were in excess of two meters per stroke and therefore a four meter stroke cycle must be completed in approximately one second if that protocol was used in the laboratory assessment, which is physiologically unrealistic.

Based upon our findings it would appear that elite SUP athletes have high maximal aerobic capacity which compares well to other water based athletes. Laboratory and field based measurements are highly correlated and can be used to assess SUP athletes provided the tendency for the field based measurements using the K4b2 unit to consistently measure higher values is noted.

PRACTICAL APPLICATIONS

SUP is a new sport and recreational activity in which little scientific research exists. Our results demonstrate the aerobic capacity representative of elite level SUP athletes which can be used by sport scientists and coaches as targets. Elite level SUP athletes have aerobic capacities similar to other elite water based athletes highlighting that a high level of aerobic fitness is important for competitive SUP. This study demonstrates that SUP athletes can be assessed for maximal aerobic power in the laboratory with high correlation to field based measures.

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FIGURES AND TABLES

	Group (n=10)	Males (n=6)	Females (n=4)
Age (yrs)	35.8±9.55	34.50±6.03	37.75±14.32
Height (cm)	174.00±0.45	179.83±6.91	165.25±4.27
Weight (kg)	75.59±11.44	81.32±6.41	67.00±12.66
BMI (kg/m^2)	24.87±2.42	25.14±1.36	24.46±3.77
Body Fat (%)	15.87±7.40	11.13±2.79	22.98±6.25

Table 1: Participant demographics. Mean ± SD.

	Laboratory	Field
VO_2max (ml/kg/min)	43.20±6.67	45.48±6.96*
V_E STPD (L/min)	118.09±24.79	123.63±41.68
Respiratory Exchange Ratio	1.13±0.05	1.16±0.08
Heart Rate (bpm)	180.9±15.58	183±9.89
Peak Speed (m/s)	2.17±0.13	3.09±0.32**

Table 2: Laboratory versus field based results of maximal aerobic power. * = *P*=.037, ** *P*=000. Results expressed as mean±SD.

Figure 1: Lab based testing on the SUP ergometer and field based testing with the K4b2 portable unit.

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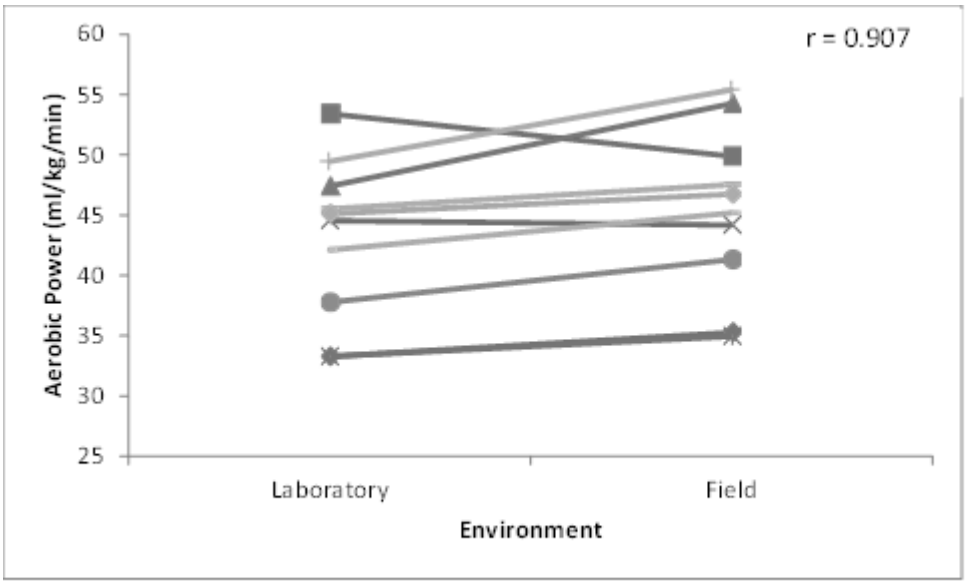

Figure 2: Laboratory and Field based measurements of maximal aerobic power.

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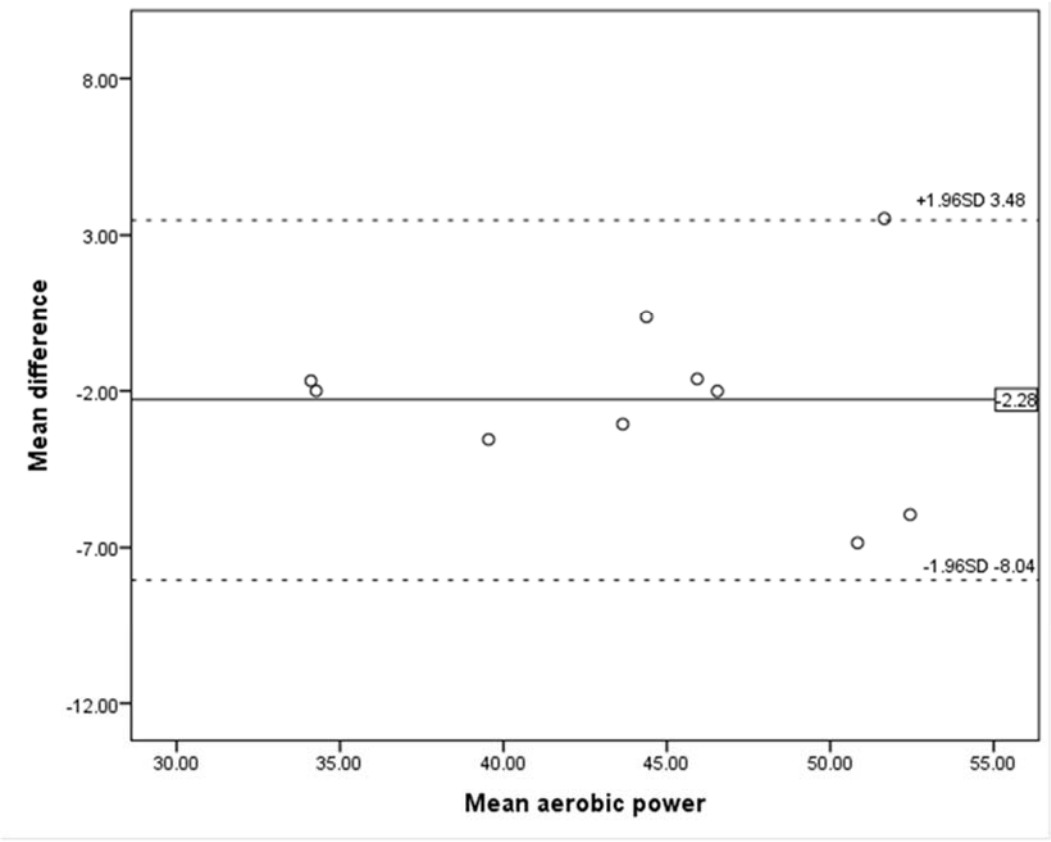

Figure 3: Bland Altman plot displaying mean difference between the two measures and 95% CI.

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